Data Source Discovery in Coalition Operations

Syndicate 2 Final Report

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2.0 EXECUTIVE SUMMARY

The group addressed the issue of information and data source discovery in a real-time NATO or coalition operational environment. The group analyzed a conceptual approach to the design of an interactive visualization system to be used for data resource discovery. Needs and requirements are discussed through a process of answering (in part) six key questions that would guide system design. The group chose a use-case for illustration. The group concludes by recommending that the issue of data resource discovery, understanding, and availability in a NATO operation be further studied.

3.0 INTRODUCTION

3.1 NATO Operational Problem Statement

In a multinational coalition operational environment, the effectiveness of a commander's decision-making can be impaired during critical real-time planning activities by the lack of knowledge of information resources. High-tempo decision makers require an awareness and understanding of the existence, availability, and quality of time-dependent information resources. These resources can include national, coalition, theater, organic, or global sensors, systems and platforms, or other data sources (eg. open press, media, www, … etc.).

From the Operational Commander (User) –

> ***"…NATO nations in an operational context, often do not adequately share national information assets and products in an efficient and effective manner…"***

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3.2 Question Addressed by IST-036/RWS-005 Syndicate 2

How might a visualization system assist in the understanding of the existence, availability, and quality of information resources in a distributed NATO or coalition operational environment?

3.3 Applicability to Counter-Terrorism Application

Counter-terrorism activities often involve multi-national or coalition efforts. Additionally, non-military resources such as local law enforcement and emergency response personnel may be utilized, each having its own as well as shared information and data resources. Access and understanding of these resources can play a vital role in a commander's operational effectives and situational awareness.

4.0 PROBLEM ANALYSIS

In order to conduct an analysis of this problem, the group chose to follow the VisTG[1] model of visualization system design. This model was chosen in order to use the posed questions as guidance in the analysis process. The group further developed a brief straw-man and operational scenario, in order to illustrate the key features and issues to be addressed.

4.1 Example Use Case

To assist the analysis and understanding of this problem, the group explored the potential situation of a downed pilot during a tactical mission tasking. The tactical operational commander needs to obtain the necessary information in order to plan and execute an extraction operation. Following is a possible chain-of-events as they would occur on a commander's data.

1) Pilot goes down.
2) Transponder on aircraft is activated.
3) Table console (TC) in command and control (C&C) flashes red dot.
4) Commander zooms TC into pilot location to view terrain/image model at fine resolution.
5) J2 and J3 initiate a data availability request for area of interest (AOI) around the pilot.
6) Data list is retrieved from metadatabase that is continuously updated by Allies. Such a list might include:

Source Platform	Available Data	ETA	NIC
UAV	High Resolution IR	5 min	US-12
Platoon	Visual	30 min	NOR-2
Satellite	1 m Multispectral	3 hours	CAN-3
Special Forces	Medical Condition	1 hour	UK-1
F-16	Sighting	-10 min	FRA-4

7) J2 and J3 chose from the above-noted list then initiate AOI data requests to all relevant National Intelligence Centers (NIC's) including commander's own NIC.

[1] The VisTG Model identifies a hierarchical, nested processing loop for visualization. The model poses six key questions to assist in the design of a visualization system.

8) Metadatabase indicates probable time of data retrieval. In addition, answers are received from NIC's for non-standard data requests.
9) As data is received or retrieved, update the TC and provide personal reports for J2 and J3 to the Commander. Objects of interest would be displayed as icons that are easily identified at a glance.
10) Have TC report the percentage of data downloaded from each NIC and expected time of receipt of remaining data. These might be displayed on the TC as NIC-specific information bars.
11) Have preset datasets (groups of data types) selectively available at the touch of a button. These could be pushed by the commander or requested from the J2 or J3. The dataset would also be editable to include more or less sets.
12) Display the "probability of detection" or "probability missing data" for any variable the commander specifies.
13) Predict and display the enemy forces' situational awareness of AOI.
14) Enable ability to gain control of, and task, mobile sensors.

4.2 Using the VisTG Reference Model for Design

Several times during the workshop it was mentioned that one of the problems with coalition operations is that nations do not necessarily make pass to the coalition command all the information they have. Some of this information might be made available on request, some might be made available after being sanitized, and some might not be made available outside the national command. Furthermore, the command staff may find for particular situations that unconventional information sources are both available and useful.

Accordingly, an appropriate task for the Syndicate seemed to be to suggest a visuaalisation system that would assist a commander and the command staff to determine what sources might be able to provide what kinds of information relevant to the situation of immediate interest. It was assumed that very many different kinds of data source might be available, both official and unofficial, and that the nature of all of them would be contained in some kind of a dataspace accessible to the user (the command staff). There would be too many possible data sources for any staff officer to be able to remember all of them reliably.

The method chosen for the development was the VisTG Reference Model illustrated in Figure 1. To make the example concrete, a use-case was chosen, in which a plan was to be developed for recovering a downed pilot.

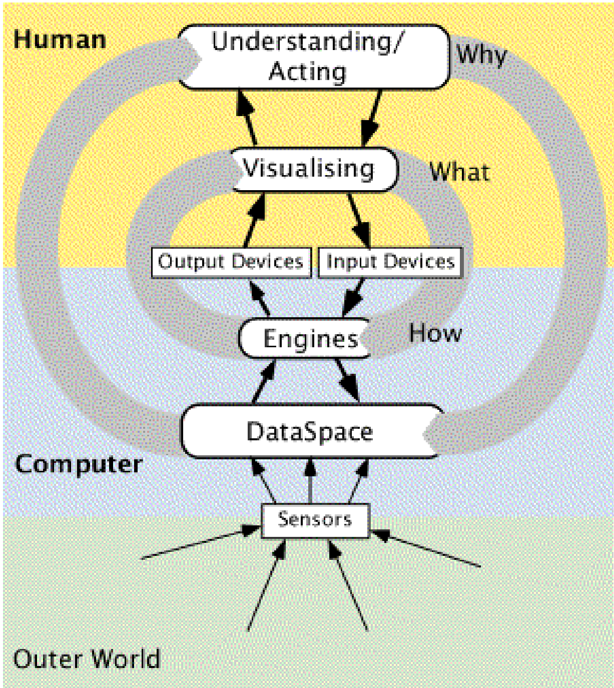

Figure 1

The VisTG Reference model treats visualisation as one of two routes to understanding, the other being analysis. The user wants to understand and to act upon some dataspace that contains information about the world of interest. Visualisation may be considered similar to intuition, which both supports and is supported by analysis.

The Reference Model does not explicitly address the analytic process, which has different presentation requirements than does visualisation. In particular, analysis ordinarily deals in individuated entities and their relationships, whereas visualisation is more concerned with patterns in an extended context.

Analysis is impeded by clutter in the presentation, whereas visualisation may be aided by the same clutter, clutter which is similar to that with which every person is confronted every moment of the day. To put it crudely, visualisation depends heavily on context, whereas analysis depends on individuation and is normally context-free.

4.3 Design of a Data-Source Discovery System

The design process using the VisTG Reference Model proceeds in stages. The model assumes a series of nested loops, each based around the achievement of some purpose, or goal, and the perceptions needed by the user if progress toward achieving that goal is to be assessed. At any one level, there may be several parallel loops, and any one of these may simultaneously serve more than one purpose at a higher (outer) loop level. For each of these many loops, the method identifies six basic questions, which can be summarized:

1) What is the purpose of the loop?
2) What does the user need to perceive if the purpose is to be achieved?
3) What does the user need to be able to do to achieve the desired perception?
4) What impediments might detract from the user's ability to perceive (including lack of user training)?

5) What impediments might reduce the user's ability to act to affect the necessary perception (including lack of user training)?

6) What provisions might be available for alerting the user to portions of the dataspace potentially relevant to the purpose of the loop?

Outer (Level 1) Loop

The first stage of the design process, then, must be to assert the purpose that a given loop is to serve. In the problem at hand, the system to be designed is supposed to help a command staff (including the commander) to be able to understand those data sources that might reasonably be expected to have, and to be willing to provide, data relevant to the situation of immediate interest, including understanding of their probable reliability, relevance, and latency (time to deliver the information).

Translating these requirements to the use-case, relevant data sources include those that could potentially supply information about:

- The location of the downed aircraft and its pilot
- The pilot's state of health
- The character and socio-political environment of the people in the region
- The location, numbers, identity, and movement of nearby blue, red and orange forces
- The local physical environment, such as terrain, weather, trafficability, visibility, and so forth.

The answer to Question 1 for the outer loop (i.e., Q 1.1), *What is the purpose of the system*, then, is that the system is to help the command staff to distinguish from a potentially very large number of official and unofficial data sources those that could potentially supply any of the desired kinds of information, and to prioritize among the potentially relevant ones those that would be most likely to be useful within the time frame available for the operation.

Question 1.2, *What does the user need to perceive*, is about the relationship of the sources to the necessary data. The data requirement information is paramount, the source is a means to acquire it. This means that the user does NOT need to perceive available data as an attribute of the set of potential data sources. Rather, sources that could provide data such as location, politico-social climate, or local weather, should be presented as attributes of the data type, however that presentation is instantiated. The user knows the required data, and needs to be able to use that knowledge as an "index" into the potentially large set of possible data sources. The system must be able to present the data so that the user can see not only which sources can provide which specific kinds of data, but also the likelihood of getting the information, its probable reliability, and the probable delay (latency) before the information is made available.

Question 1.3, *What does the user need in order to be able to act to achieve the desired perception*, is about the user's ability to let the system know what kinds of data are desired, so that the system can search its dataspace to determine what sources might be able to provide them. For example, if the user wants to contact a known friendly person in a town near the downed pilot, a local telephone directory would be a useful data source. A taskable UAV might be available to provide detailed terrain information, and one might actually be near the place in question, though tasked for some other purpose. A satellite image or a meteorological officer might be useful data sources if the required information is the local weather in the next few hours. The same satellite image might be a useful data source for other aspects of the physical environment. SIGINT and HUMINT sources collated by coalition and national intelligence cells might provide information about force movements, but some national cells might divulge only sanitized versions, and then only after appreciable delay.

The user's actions need to be able to give the system enough information that the system is able to present to the user what is necessary to perceive. The user must be able to specify, for example, limits on latency. Under some circumstances, retrieving the downed pilot might require no more than asking the local mayor to put the pilot on a bus, with a promise to refund the ticket price. Under others, a delay of 30 minutes might make the difference between success and failure of the retrieval mission in hostile territory. The use has to be able to let the system know the degree to which latency matters, just as much as to let the system know what kinds of data are required.

Question 1.4 *What impediments might detract from the user's ability to perceive what is necessary* is about both external impediments, such as the uncertain willingness of National Intelligence Cells to release information they may be known to have, and internal impediments such as the user's lack of knowledge that certain kinds of data or sources of data might be accessible or useful. The latter component may be characterized as possible lack of training or experience. The former, however, can be treated directly, and answered, at least in part, by saying that some sources may not identify the kinds of data they are willing to provide on request. Consequently, the appropriate linkages would not occur in the database and could not be presented by the system.

Question 1.5 *What impediments might detract from the user's ability to act to generate the desired perception* is about the user's ability to get out of the database the displays that would show the immediately useful sources, the usefulness of the data they could provide, and the means to acquire the information from the useful sources. It is a question about user control of the content of the presentation displays (sometimes erroneously called the "visualisations"). An example of a potential impediment might be an inability to specify the relevance of a sufficient range of data attributes, either because of restrictions in available control menus or data glossaries, or because of inadequate user training in the use of a complex interface. In the use-case, for example, the system might make it difficult for the command staff to specify that they needed to ascertain how long it would take to acquire imagery from a UAV that might already be in the vicinity or that might have to be tasked to take off on a specific mission related to the retrieval of tha downed pilot. This information might affect the relevance level of other possible sources of similar data.

Question 1.6 *What provision is there for alerting the user to potentially useful regions of the dataspace* concerns autonomous actions performed by the system under general rather than specific control of the user. The user (or system designer) may set up criteria for determining what patterns in the dataspace warrant being labelled "potentially useful", but the system does the labelling independently of immediate user control. Alerting occurs when the system affects the presentation so as to draw the user's attention, however momentarily, to the "potentially useful" aspect of the dataspace. Typically, the labelling will be affected by prebuilt scenarios. For the use-case of a downed pilot, the system might be set up to highlight data sources related to the attributes mentioned above: location, terrain, weather, pilot's health, local socio-political environment, force dispositions, etc. For other scenarios, other constellations of data sources might be highlighted.

Engine (Level 2) Loops

The questions discussed above are all cast in terms of the purpose of the system as a whole, and as a group, they specify the requirements and illustrate some possible pitfalls to be avoided in the design. The design process builds on the answers to the Level 1 questions, using them as partial specifications for questions that define Level 2 loops.

Generically, any visualisation system has four kinds of engine loops at level 2:

- Navigation Engines, which allow the user to move around the dataspace,
- Data Selection Engines, which allow the user to choose subsets of the data for manipulation,

- Algorithm Selection Engines, which allow the user to determine how the selected data subsets are to be manipulated, and
- Algorithm Execution Engines, which do the actual manipulation of the data, including the preparation of presentations such as 2-D and 3-D displays, textual and tabular representations, or auditory or haptic displays.

In a detailed design, each of the six questions should be addressed for each engine in each of the four classes of engines. For the present purposes, it may suffice to illustrate some examples and suggest the implications of the answers for the presentation-level systems (e.g. screen, keyboards, etc.).

Navigation Engines allow the User to examine different parts of the dataspace. They tend to work closely with Data Selection Engines. Indeed, data selection can be an aspect of navigation, in that it can refine whole sections of the dataspace, in effect reducing the volume in which navigation might occur. The user may navigate (alter the viewable part of the dataspace) and then select within the displayed parts of the dataspace, or may first select using definable attributes, and then navigate within the selected subset of the data. In the end, however, the result is a data subset on which selected algorithms may operate, both to change the content of the dataspace and to prepare for the actual user presentation of the computed results. The six wuestions can be applied to each engine within each class. Here, for simplicity, the system will be treated as if there were only one engine in each class.

Navigation engine(s):

Q2.1.nav (Purpose) The user needs to be able to navigate so that relevant data sources are viewable.

Q2.2nav (Perceptual requirement) The user needs to be able to see the relevance of data sources brought into view, to be able to see where to navigate so as to view other data sources, and to be able to see the functions of any control mechanisms provided to change the view.

Q2.3nav (Ability to act) Controls must be available to allow the user to affect the data sources displayed, in such a way that the various attributes of the data sources may be used to affect which ones are actually displayed.

Q2.4nav (Possible impediments to perception) Inability to see the functions of available controls (either because of presentation design or because of lack of training); inability to see where in the dataspace might be a useful region to examine; inability to see the relevance of potential data sources (because of presentation design flaws or lack of training).

Q2.5nav (Possible impediments to action) Failure of design to provide appropriate navigation controls. Complexity of control mechanisms requiring use of controls not simultaneously accessible.

Q2.6nav (Potential Alerting systems) Agents might be developed to indicate useful data sources for a variety of standard scenarios, and thereby to alert the user to possibilities that might not be immediately obvious.

Data Selection Engine(s):

Q2.1DS (Purpose) To allow the user to select those data sources most likely to be immediately useful (and in a broader appreciation of the system in use, thereby to allow the user to begin the process of acquiring the data from the selected sources).

Q2.2DS (Perceptual Requirement) To allow the user to perceive which sources are currently selected, and to perceive how to alter the selected subset by addition or removal (i.e. to perceive the means of controlling the selection).

Q2.3DS (Ability to Act) Means must be provided for the user to add to or exclude from the selection by data attribute, by source identity or attribute (e.g. nationality, latency, or reliability), by location within the display, or by other suitable attribute.

Q2.4DS (Possible impediments to necessary perceptions) Inability to distinguish selected from non-selected data sources (e.g. colour blindness); Inability to perceive data attributes relevant to selection; Failure in the design to make apparent the functions of selection controls.

Q2.5DS (Possible impediments to action) Failure to provide means for selection by potentially useful source or data attributes. Lack of training in the use of selection mechanisms actually provided.

Q2.6DS (Alerting) Ambiguities of selection could be represented and opportunity for disambiguation provided.

There is no need here to analyze the possible loops for Algorithm selection and execution loops. Among the algorithms might be those that enable the user actually to begin the process of acquiring the data from the source, such as by initiating the tasking of a UAV, by looking up a phone book for the locality of the downed pilot, by generating a formal request for data from a national NIC, and so forth. All of these represent operations on the data, and have implications for the actual presentations generated by the system. However, the question at issue is the discovery of the set of most useful data sources for the user's immediate problem, which, in the use-case, is to generate a plan for the recovery of the downed pilot. The actual generation of the plan is outside the scope of the present discussion.

The answers to the Engine-level questions have implications for the physical design of the presentations and the control input devices. For example, the answers to Q2.2nav and Q2.2DS suggest that at least two kinds of display would be useful in the use-case example, one map-based, to allow theuser to limit the range of data sources to those potentially able to provide information relevant to the area of interest, and the other somewhat VITA-like in which data types and sources are cross-linked so that sources with much coordinated relevant data could be given selection priority (see Annex).

Likewise, the answers to the Q2.3 questions indicate the need for clear and clearly labelled controls for exploding aggregated data sources, and for quasi-spatial navigation within a displayed 2-D or 3-D presentation space (especially with map or VITA-like displays). For data selection, controls based on area or volume selection within the presentation space, or on linguistically labelled data or source attributes marking selection boundaries numerically or using sliders, would seem to be necessary.

The detailed design of the presentations forms the third loop level, and as with the other two levels, the purposes of the presentations are determined by the answers to the questions at the level immediately above. Some of the more obvious implications are indicated above, but for a full design, each of the level 2 answers needs to be seen as a generator of purpose for one or more elements of the presentation displays and of the control input mechanisms. Once those purposes have been defined, the actual presentations and the means whereby the user can navigate within them and move among them can be specified using the same pattern of five questions (the sixth being Q 1, about Purpose, which has already been answered).

At each level, when there are parallel loops, the designer must ask about the possibilities for interference among them. If the user is paying attention to one, does that detract from the immediate usefulness of another? Does the provision of multiple perceptual possibilities create confusion or context? Are the required actions mutually incompatible? Is the question of the moment one of precision or of pattern? All such questions must be resolved, whether by design or by default, when a system is finally built.

Annex: The VITA Presentation

The VITA engine suite (Jacobson, McIntyre and Romet, Workshop ppresentation Session 6) was developed in the context of discovering patterns of concepts within Web pages, but is not limited to that area of application. It contains both Data Selection and Algorithm Execution engines, and Algorithm Selection is to some extent also incorporated in the form of prior user control.

In the VITA original design, one or more "Query" instances are submitted to search engines. Each Query contains a set of concepts (keywords, in the initial implementation), and the search engines return for display Web pages that contain at least a threshold number of concepts. In the 3-D VITA display, the Queries are displayed as nodes in one plane, the concepts as nodes in a second plane, and the Web pages that pass the threshold test as nodes in a third plane. Concept nodes are shown as linked to Query nodes on the one side, and to Web page nodes on the other. The placement of concept and Web page nodes within their respective planes is controlled by a self-organizing process that locates similar entities near each other.

In the context of a data source discovery process, a similar display might substitute Standard Scenarios for the Queries, Data Requirements for the Concepts, and Data Sources for the Web pages. The user's eye would tend to be drawn to those data sources most relevant for the scenario at hand. If more than one scenario applied, the display would be essentially the same, except that the "Query" plane would be more heavily populated, as is the case with "standard" VITA when displaying the combined results of several independent Queries.

The standard VITA display allows for variable representation of concept and page nodes according to their attributes, such as whether the page has been examined. Using a VITA-like display for Data Source discovery, valuable attributes might affect either the placement or the representation of the node, or both. For example, probable latency might affect the transparency or some shape-related iconic value of the data source representation, or might affect its location above or below its "natural" representation plane. Or, if the user were given the ability to indicate to the system the relative importance of attributes such as latency and reliability, the data sources might be represented in colour variations that represent the important attributes. There are many possibilities for enhancing the standard VITA presentation to take advantage of the requirements brought out by the "six-question" analyses generated by using the VisTG Reference Model.

5.0 RESEARCH AND DEVELOPMENT ISSUES

The following are some research issues that should be addressed to achieve the desired capability.

1) Information translation/transformation – how can general information requests/queries be translated into specific requests for data? For example if a user wants to locate, characterize and identify a specific target, what is the relationship between the target type and observable quantities? Need to link:

   target information -> observable quantities -> sensors/sources

   Note the description of the ontology-driven sensor independencies (by E. Jungert) is pertinent here. Special challenges here include:

   - situation in which multiple sources/sensors might work in concert to achieve requisite information (e.g. observing different attributes may lead to identity knowledge)
   - understanding how to relate accuracy requirements to sensor/source performance.

2) Representation/Propagation of Uncertainty – How can we link information requirements (confidence/uncertainty) to requirements for the information sources. For Example, if we need to know the location of a target within one meter, what does this imply about the number of measurements, accuracy of angle and range measurements, etc. A more difficult issue involves the link between confidence in target identity and observable features. How can we show what is observable/knowable and what cannot be observed or known.

3) Visualization of source availability/performance – How can we readily show the user the availability and capability of sources. It is one thing, for example, to show the footprint of an airborne based image sensor (e.g. to show what the sensor could "see"). It is more difficult to understand how to show how multiple sensors could be used within an area to identify a target type (Steinberg & Pack, this workshop).

4) Maintenance of a Metadatabase (data about data) – Data about what sensor data/information is potentially available to NATO forces needs to be stored in a common format. This will enable searches and queries between national intelligence centers. This database will be maintained and updated by all involved forces as new data is made available or existing data is removed. The database can include reference to information such as IR images owned by a country, the phone number to a mayor in a nearby city, or the URL of a site containing European train tables. Each metadata entry would include at least the following information: senor type, data quality, area covered, time of acquisition, time to become available, and how to access the data.

5) How to discover potential data sources – Incorporate a method for discovering data sources that have the potential of delivering relevant data. For example, the fact that a UAV is flying within the vicinity of the AOI needs to be discovered such that it might be rerouted to fly over the AOI.

    - Nature of the location and area of the downed aircraft. What are the physical and environmental factors?
        - Potential data sources – organic video, satellite imagery, weather maps
    - Physiological assessment of the pilot. State of vitals. Mobility.
        - Potential data sources – radio comms, cell phone?
    - Sociological and political environment in the area? Status of civilian crowds. Attitudes towards blue forces. State of local police, emergency personnel activities, etc.
        - Potential data sources – Intelligence packages, video, local media, on-site personnel and forces
    - Status, make-up, threat level, and locations of all friendly, hostile, and other forces in the area.
        - Potential data sources – organic and/or air/space based multi-national sensors, Intelligence packages
    - Current status of extraction team forces.
        - Potential data sources – organic command and control system

For each information and data source, it is also required to know the timeliness of the data, its reliability and relevance into the future for some period of time. Additionally, what is the time required to get information from these data sources?

6.0 CONCLUSIONS

The group recommends that the issue of the knowledge and availability of all relevant and potentially relevant sources of data and information by NATO commanders in a multinational or coalition operation be further studied and analyzed. The group further recommends that the design of an interactive visualization system that would assist the commander in information and data resource and sensor discovery be explored.

SYMPOSIA DISCUSSION – SYNDICATE 2

Comment:
In Step 6 it is J2 and J3 who select the best sensors.

Question:
Is there automation, or is this a manual process?

Response:
Automation would be nice, but would depend on the sophistication of the preset databases. The idea is to get the requests out as soon as possible.

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Summary

- The problem of data & information resource discovery
- Analysis Approach
- Use Case
- Recommendations
- Conclusion

NATO Operational Problem

- *…In a multinational coalition operational environment, the effectiveness of a commander's decision-making can be impaired during critical real-time planning activities by the lack of knowledge of information resources…*

Question Addressed by IST-036/RWS-005 Syndicate 2

- *How might a visualization system assist in the understanding of the existence, availability, and quality of information resources in a distributed NATO or coalition operational environment?*

Problem Analysis

- VisTG Model Analysis – Key Questions

What is the user trying to achieve at this point in time?

What does the user need to perceive?

What does the user do influence the goal?

What are the impediments to perceiving what is necessary?

What impediments might affect the user's ability to act appropriately?

What provisions should there be to alert the operator when something needs attention?

A Sample Use case

Source Platform	**Available Data**	**ETA**	**NIC**
UAV	High Resolution IR	5 min	US-12
Platoon	Visual	30 min	NOR-2
Satellite	1 m Multispectral	3 hours	CAN-3
Special Forces	Medical Condition	1 hour	UK-1
F-16	Sighting	-10 min	FRA-4

Research and Development Issues

- Metadatabase
- Information translation/transformation
- Representation/Propagation of Uncertainty
- Visualization of source availability/performance
- How to discover potential data sources

Conclusions

- Study of the entire issue of data/information resource availability
- Design of a visualization system to assist in data source discovery